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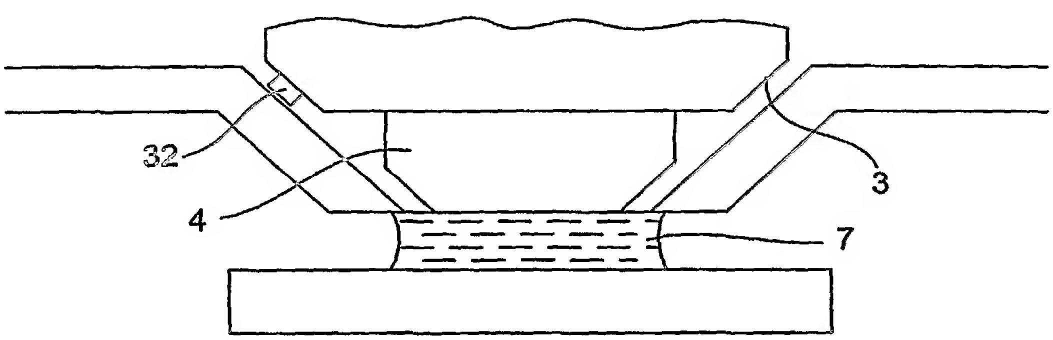
(54) **Title:** CLEANUP METHOD FOR OPTICS IN IMMERSION LITHOGRAPHY



(57) **Abstract:** An immersion lithography apparatus has a reticle stage arranged to retain a reticle, a working stage arranged to retain a workpiece, and an optical system including an illumination source and an optical element opposite the workpiece for having an image pattern of the reticle projected by radiation from the illumination source. A gap is defined between the optical element and the workpiece, and a fluid-supplying device serves to supply an immersion liquid into this gap such that the supplied immersion liquid contacts both the optical element and the workpiece during an immersion lithography process. A cleaning device is incorporated for removing absorbed liquid from the optical element during a cleanup process. The cleaning device may make use of a cleaning liquid having affinity to the absorbed liquid, heat, a vacuum condition, ultrasonic vibrations or cavitating bubbles for the removal of the absorbed liquid. The cleaning liquid may be supplied through the same fluid-applying device provided with a switching device such as a valve.

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CLEANUP METHOD FOR OPTICS IN IMMERSION LITHOGRAPHY

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application No. 60/462,556 filed April 11, 2003 and to U.S. Provisional Patent Application No. 60/482,913 filed June 27, 2003, which are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

This invention relates to an immersion lithography system and more particularly to methods, as well as systems, for cleaning up the optical element that contacts and absorbs water in the process of immersion lithography.

Immersion lithography systems, such as disclosed in WO99/49504 which is herein incorporated by reference for describing the general background of the technology as well as some general considerations related thereto, are adapted to supply a liquid into the space between a workpiece such as a wafer and the last-stage optical element of an optical system for projecting the image of a reticle on the workpiece. The liquid thus supplied improves the performance of the optical system and the quality of the exposure.

The liquid to be supplied may be water for light with wavelength of 193nm although different liquids may be necessary for light with other wavelengths. Because the last-stage optical element of the optical system is exposed to the liquid, there is a possibility that some of the liquid may be absorbed. This possibility is particularly high if the last-stage optical element of the optical system is a lens because calcium fluoride is a common lens material for lithography systems while it is a hygroscopic material, ready to absorb water from the surrounding environment.

The absorbed water may cause several problems. Firstly, it may degrade the image projected by the lens by changing the refractive properties of the lens or by causing the lens to swell to thereby change the geometry of the lens. Secondly, it may cause long-term degradation of the lens due to chemical effects.

Conventional air-immersion exposure lithography systems require the optical elements to be made detachable for maintenance work such as when they are cleaned.

It is a cumbersome and time-consuming operation, however, to remove an optical element and to reset it after it is cleaned or to exchange an optical element for a new one.

It is therefore an object of this invention to provide systems and methods for periodically removing the water from the lens such that the amount of absorbed water will not reach a critical level and the degradation of the image and the long-term damage to the lens can be prevented.

It is another object of the invention to provide systems and methods for making the maintenance of the optical element of an immersion lithography apparatus easier and thereby improving the useful lifetime of the optical element.

SUMMARY OF THE INVENTION

Immersion lithography apparatus of this invention includes a reticle stage arranged to retain a reticle, a working stage arranged to retain a workpiece, an optical system including an illumination source and an optical element opposite the workpiece for having an image pattern of the reticle projected thereon by radiation from the illumination source while defining a gap between the optical element and the workpiece and a fluid-supplying device for providing an immersion liquid between and contacting both the optical element and the workpiece during an immersion lithography process. The apparatus also includes a cleaning device to clean the optical element. Throughout herein, the term "cleaning" will be used to mean both removing immersion liquid that has been absorbed into the optical element and removing dirt, debris, salts and the like.

Many different kinds of the aforementioned cleaning device may be used within the scope of this invention. For example, it may comprise a cleaning liquid having affinity to the immersion liquid to be contacted with the optical element. If the immersion liquid is water, ethanol may serve as the cleaning liquid. As another example, the cleaning device may include a heat-generating device for heating the optical element and/or a vacuum device for generating a vacuum condition on the optical element.

Ultrasonic vibrations may be used for removing the absorbed liquid. An ultrasonic vibrator such as a piezoelectric transducer may be attached to the housing

for the optical element or placed opposite the optical element such that the vibrations may be transmitted to the optical element through a liquid maintained in the gap.

Alternatively, cavitating bubbles may be used for the removal of the absorbed liquid. A pad with fins may be used to generate cavitating bubbles in a liquid maintained in the gap between the pad and the optical element.

According to still another embodiment of the invention, the nozzles through which the immersion liquid is supplied into the gap between the workpiece and the optical element may be used to alternatively supply a cleaning liquid by providing a flow route-switching device such as a switch valve.

With a system and method of this invention, the cleaning procedure becomes significantly easier and faster because there is no need to detach the optical element to be cleaned and the cleaning process improves the useful lifetime of the optical element.

BRIEF DESCRIPTION OF THE DRAWING

The invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic cross-sectional view of an immersion lithography apparatus on which methods and systems of this invention may be applied;

Fig. 2 is a process flow diagram illustrating an exemplary process by which semiconductor devices are fabricated using the apparatus shown in Fig. 1 according to the present invention;

Fig. 3 is a flowchart of the wafer processing step shown in Fig. 2 in the case of fabricating semiconductor devices according to the present invention;

Fig. 4 is a schematic drawing showing a side view of a portion of the immersion lithography apparatus of Fig. 1;

Fig. 5 is a schematic side view of a portion of another immersion lithography apparatus having an ultrasonic transducer attached so as to serve as its cleaning device;

Fig. 6 is a schematic side view of a portion of still another immersion lithography apparatus having a piezoelectric cleaning device below its optical system;

Fig. 7 is a schematic diagonal view of an example of piezoelectric device;

Fig. 8 is a schematic side view of a portion of still another immersion lithography apparatus having two mutually attached piezoelectric planar members as the cleaning device;

Fig. 9 is a schematic side view of a portion of still another immersion lithography apparatus having a bubble-generating pad as the cleaning device; and

Fig. 10 is a schematic side view of a portion of still another immersion lithography apparatus having a switching device incorporated in the fluid-supplying device.

Throughout herein, components that are similar or equivalent may be indicated by a same symbol or numeral in different figures and may not be explained repetitiously for the simplicity of description.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Fig. 1 shows an immersion lithography apparatus 100 on which cleaning methods and systems of this invention may be applied.

As shown in Fig. 1, the immersion lithography apparatus 100 comprises an illuminator optical unit 1 including a light source such as an excimer laser unit, an optical integrator (or homogenizer) and a lens and serving to emit pulsed ultraviolet light IL with wavelength 248nm to be made incidence to a pattern on a reticle R. The pattern on the reticle R is projected on a wafer W coated with a photoresist at a specified magnification (such as 1/4 or 1/5) through a telecentric light projection unit PL. The pulsed light IL may alternatively be ArF excimer laser light with wavelength 193nm, F_2 laser light with wavelength 157nm or the i-line of a mercury lamp with wavelength 365nm. In what follows, the coordinate system with X-, Y- and Z-axes as shown in Fig. 1 is referenced to explain the directions in describing the structure and functions of the lithography apparatus 100. For the convenience of disclosure and

description, the light projection unit PL is illustrated in Fig. 1 only by way of its last-stage optical element (such as a lens) 4 disposed opposite to the wafer W and a cylindrical housing 3 containing the rest of its components.

The reticle R is supported on a reticle stage RST incorporating a mechanism for moving the reticle R in the X-direction, the Y-direction and the rotary direction around the Z-axis. The two-dimensional position and orientation of the reticle R on the reticle stage RST are detected by a laser interferometer (not shown) in real time and the positioning of the reticle R is effected by a main control unit 14 on the basis of the detection thus made.

The wafer W is held by a wafer holder (not shown) on a Z-stage 9 for controlling the focusing position (along the Z-axis) and the tilting angle of the wafer W. The Z-stage 9 is affixed to an XY-stage 10 adapted to move in the XY-plane substantially parallel to the image-forming surface of the light projection unit PL. The XY-stage 10 is set on a base 11. Thus, the Z-stage 9 serves to match the wafer surface with the image surface of the light projection unit PL by adjusting the focusing position (along the Z-axis) and the tilting angle of the wafer W by the auto-focusing and auto-leveling method, and the XY-stage 10 serves to adjust the position of the wafer W in the X-direction and the Y-direction.

The two-dimensional position and orientation of the Z-stage 9 (and hence also of the wafer W) are monitored in real time by another laser interferometer 13 with reference to a mobile mirror 12 affixed to the Z-stage 9. Control data based on the results of this monitoring are transmitted from the main control unit 14 to a stage-driving unit 15 adapted to control the motions of the Z-stage 9 and the XY-stage 10 according to the received control data. At the time of an exposure, the projection light is made to sequentially move from one to another of different exposure positions on the wafer W according to the pattern on the reticle R in a step-and-repeat routine or in a step-and-scan routine.

The lithography apparatus 100 being described with reference to Fig. 1 is an immersion lithography apparatus and is hence adapted to have a liquid (or the "immersion liquid") 7 of a specified kind such as water filling the space (the "gap") between the surface of the wafer W and the lower surface of the last-stage optical

element 4 of the light projection unit PL at least while the pattern image of the reticle R is being projected on the wafer W.

The last-stage optical element 4 of the light projection unit PL may be detachably affixed to the cylindrical housing 3 and is designed such that the liquid 7 will contact only the last-stage optical element 4 and not the cylindrical housing 3 because the housing 3 typically comprises a metallic material and is likely to become corroded.

The liquid 7 is supplied from a liquid supply unit 5 that may comprise a tank, a pressure pump and a temperature regulator (not individually shown) to the space above the wafer W under a temperature-regulated condition and is collected by a liquid recovery unit 6. The temperature of the liquid 7 is regulated to be approximately the same as the temperature inside the chamber in which the lithography apparatus 100 itself is disposed. Numeral 21 indicates supply nozzles through which the liquid 7 is supplied from the supply unit 5. Numeral 23 indicates recovery nozzles through which the liquid 7 is collected into the recovery unit 6. It is to be reminded, however, that the structure described above with reference to Fig. 1 is not intended to limit the scope of the immersion lithography apparatus to which the cleaning methods and devices of the present invention are applicable. In other words, it goes without saying that the cleaning methods and devices of the present invention are applicable to immersion lithography apparatus of many different kinds. In particular, it is to be reminded that the numbers and arrangements of the supply and recovery nozzles 21 and 23 around the light projection unit PL may be designed in a variety of ways for establishing a smooth flow and quick recovery of the immersion liquid 7.

A method embodying this invention of removing the portion of the liquid 7 such as water absorbed by the last-stage optical element 4 made of a hygroscopic material, as well as dirt, debris, etc., is explained next with reference to Figs. 1 and 4. After the wafer W is exposed with light from the illuminator optical unit 1 through the light projection unit PL in the presence of the liquid 7 as shown in Fig. 1, the liquid 7 is removed from underneath the light projection unit PL and a cleaning device 30 is brought into contact with the last-stage optical element 4 as shown in Fig. 4. In the case of a portable kind, as shown in Fig. 4, the cleaning device 30 may be placed on

the Z-stage 9 or the aforementioned wafer holder thereon, as shown in Fig. 4, in place of the wafer W.

Different types and kinds of cleaning device 30 can be used for the purpose of this invention. As a first example, the cleaning device 30 may be a container containing a liquid ("cleaning liquid") with a strong affinity to the immersion liquid 7 which is absorbed by the optical element 4. If the immersion liquid 7 is water, the cleaning device 30 may contain ethanol since ethanol has a strong affinity to water. Any cleaning liquid may be used provided it has a sufficiently strong affinity to the liquid to be removed and does not damage the optical element 4 or its coating. The bottom surface of the optical element 4 is soaked in the cleaning liquid for a period of time sufficiently long to reduce the level of the absorbed liquid. The cleaning device 30 is removed thereafter and the optical element 4 is ready to be exposed to the liquid 7 again.

As another example, the cleaning device 30 may contain a heat-generating device and/or a vacuum device (not separately shown). The combination of heat and vacuum on the surface of the optical element 4 causes the absorbed liquid to undergo a phase change into vapor, or to evaporate from the surface. The reduction in liquid density on the surface of the optical element 4 draws the liquid 7 that is absorbed more deeply in the element 4 to the surface.

Fig. 5 shows a third example wherein use is made of an ultrasonic transducer (or ultrasonic vibrator) 32 attached to the housing 3 of the light projection unit PL. As the ultrasonic transducer 32 (such as a piezoelectric transducer) is activated, pressure waves are generated and propagated, serving to clean the surface of the optical element 4.

During the cleaning operation in Fig. 5, the gap adjacent the optical element 4 is filled with the immersion liquid 7. In this case, the supply and recovery nozzles can continue to supply and collect the immersion liquid 7, or the supply and rec4eovery nozzles can stop supplying and collecting the immersion liquid 7. Also during the cleaning operation, the optical element 4 can face a surface of wafer W, a surface of the Z-stage 9, or a surface of another assembly.

Fig. 6 is a fourth example using a vibratory tool 34 placed below the optical element 4 to be cleaned. The tool 34 may be shaped like the wafer W with thickness more or less equal to that of the wafer W, or about 0.5-1mm, and may be made

entirely of a piezoelectric material such that its thickness will fluctuate when activated. As the tool 34 is placed below the optical element 4, like the wafer W as shown in Fig. 1, and the gap between the optical element 4 and the tool 34 is filled with the liquid 7, pressure waves are generated in the immersion liquid 7 to clean the optical element.

During the cleaning operation of Fig. 6, the gap adjacent the optical element 4 is filled with the immersion 7. In this case, the supply and recovery nozzles can continue to supply and collect the immersion liquid, or the supply and recovery nozzles can stop supplying and collecting the immersion liquid 7. In other example, the vibrator tool 34 may be a ultrasonic transducer attached to the wafer holder on a Z-stage 9, or another assembly.

Fig. 7 shows another tool 36, structured alternatively, having a plurality of piezoelectric transducers 38 supported by a planar supporting member 39.

Fig. 8 shows still another example of a cleaning device having two planar members 40 of a piezoelectric material attached in a face-to-face relationship and adapted to oscillate parallel to each other and out of phase by 180° with respect to each other. As a result, these members 40, attached to each other, will vibrate in the transverse directions, as shown in Fig. 8 in a very exaggerated manner. The vibration has node points at constant intervals where the members 40 are not displaced. The members 40 are supported at these node points on a supporting member 41. As voltages are applied to these members 40 so as to cause the vibrations in the mode described above, ultrasonic pressure waves are thereby generated and propagated through the liquid 7, and the optical element 4 is cleaned, as desired.

Fig. 9 shows still another example of a liquid removal system characterized as cleaning the optical element 4 by creating cavitating bubbles. Cavitating bubbles trapped and energized by ultrasound are high-temperature, high-pressure microreactors and intense energy released by the implosive compression of the bubbles is believed to rip molecules apart. The example shown in Fig. 9 is characterized as comprising a pad 43 with fins protruding upwards and rapidly moved horizontally as shown by an arrow below the optical element 4 with a bubble-generating liquid 17 filling the gap in between (means for moving the pad 43 not being shown). As the pad 43 is thus moved, the fins serve to stir the liquid 17 and to generate cavitating bubbles which in turn serve to clean the optical element.

Fig. 10 shows a different approach to the problem of cleaning the last-stage optical element 4 by applying a cleaning liquid on its bottom surface by using the same source nozzles 21 used for supplying the immersion liquid 7. For this purpose, a switch valve 25 is inserted between the supply nozzle 21 and the liquid unit 5 such that the immersion liquid 7 and the cleaning liquid can be supplied selectively through the supply nozzle 21.

It is again to be reminded that the cleaning methods and systems according to this invention are applicable to immersion lithography apparatus of different kinds and types, say, having different numbers of source nozzles. A switch valve as described above need not necessarily be provided to each of the source nozzles but may be provided to a group of the source nozzles.

It may be the wafer W itself or a pad 18 of a suitable kind that may be placed below the optical element 4 to provide a suitable gap in between when the cleaning liquid is thus supplied through the supply nozzles 21. This embodiment of the invention is advantageous because the same nozzles already present for supplying the immersion liquid can be utilized for the cleaning process.

Although various methods have been separately described above, it goes without saying that they may be used in combinations although not separately illustrated in drawings. For example, the pad 43 with fins shown in Fig. 9 may be used instead of the pad 18 of Fig. 10. In other words, the examples described above are not intended to limit the scope of the invention and many modifications and variations are possible within the scope of this invention. For example, a polishing pad similar to one used in chemical mechanical polishing may be used for this purpose. The cleanup procedure shown in Figs. 4-10 may be carried out with ultraviolet light. The light may irradiate the optical element 4. The light may be normal exposure light from the illuminator optical unit 1 or some other light of an appropriate wavelength for the purpose of the cleanup. In other example, the ultraviolet light for the purpose of the cleanup may be used without the cleanup procedure shown in Figs. 4-10, and may be used under a condition in which the gap adjacent the optical element 4 is filled with the immersion liquid 7 from the liquid supply unit 5. All such modifications and variations that may be apparent to a person skilled in the art are intended to be within the scope of this invention.

Again, it should be noted that any of the above described cleaning methods for removing immersion fluid absorbed by the last-stage optical element as well as salts, deposits, dirt and debris that may have accumulated. The term cleaning therefore refers to both of these phenomena herein.

Fig. 2 is referenced next to describe a process for fabricating a semiconductor device by using an immersion lithography apparatus incorporating a liquid jet and recovery system embodying this invention. In step 301 the device's function and performance characteristics are designed. Next, in step 302, a mask (reticle) having a pattern is designed according to the previous designing step, and in a parallel step 303, a wafer is made from a silicon material. The mask pattern designed in step 302 is exposed onto the wafer from step 303 in step 304 by a photolithography system such as the systems described above. In step 305 the semiconductor device is assembled (including the dicing process, bonding process and packaging process), then finally the device is inspected in step 306.

Fig. 3 illustrates a detailed flowchart example of the above-mentioned step 304 in the case of fabricating semiconductor devices. In step 311 (oxidation step), the wafer surface is oxidized. In step 312 (CVD step), an insulation film is formed on the wafer surface. In step 313 (electrode formation step), electrodes are formed on the wafer by vapor deposition. In step 314 (ion implantation step), ions are implanted in the wafer. The aforementioned steps 311-314 form the preprocessing steps for wafers during wafer processing, and selection is made at each step according to processing requirements.

At each stage of wafer processing, when the above-mentioned preprocessing steps have been completed, the following post-processing steps are implemented. During post-processing, initially, in step 315 (photoresist formation step), photoresist is applied to a wafer. Next, in step 316, (exposure step), the above-mentioned exposure device is used to transfer the circuit pattern of a mask (reticle) to a wafer. Then, in step 317 (developing step), the exposed wafer is developed, and in step 318 (etching step), parts other than residual photoresist (exposed material surface) are removed by etching. In step 319 (photoresist removal step), unnecessary photoresist remaining after etching is removed. Multiple circuit patterns are formed by repetition of these preprocessing and post-processing steps.

While a lithography system of this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and various substitute equivalents which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and various substitute equivalents as fall within the true spirit and scope of the present invention.

WHAT IS CLAIMED IS:

1. A cleanup method for optics in immersion lithography, said method comprising:

positioning a workpiece for lithography on a stage and a projection optics with an optical element above and opposite said workpiece, a gap being provided between said optical element and the workpiece;

supplying an immersion liquid into said gap such that said immersion liquid contacts said optical element and said workpiece during an immersion lithography process; and

cleaning said optical element during a cleanup process.

2. The cleanup method of claim 1 wherein said cleanup process comprises causing a cleaning liquid to contact said optical element, said cleaning liquid having affinity to said immersion liquid, whereby absorbed liquid by said optical element is removed.

3. The cleanup method of claim 2 wherein said immersion liquid is water and said cleaning liquid is ethanol.

4. The cleanup method of claim 1 wherein said cleanup process comprises causing a heating device to heat said optical element, whereby the absorbed liquid by said optical element is removed.

5. The cleanup method of claim 1 wherein said cleanup process comprises the step of generating a vacuum condition on said optical element, whereby the absorbed liquid by said optical element is removed.

6. The cleanup method of claim 1 wherein said cleanup process comprises subjecting said optical element to ultrasonic vibrations, whereby the absorbed liquid by said optical element is removed.

7. The cleanup method of claim 6 wherein said ultrasonic vibrations are generated by an ultrasonic vibrator attached to a housing for said optical element.

8. The cleanup method of claim 6 wherein said ultrasonic vibrations are generated by an ultrasonic vibrator and communicated to said optical element through a liquid in said gap.

9. The cleanup method of claim 1 wherein said cleanup process comprises generating cavitating bubbles in a liquid supplied into said gap, whereby the absorbed liquid by said optical element is removed.

10. The cleanup method of claim 1 wherein said cleanup process comprises:

providing a switching device to selectively cause said immersion liquid and a cleaning liquid to be supplied into said gap;

supplying said immersion liquid through said switching device onto said workpiece such that said immersion liquid contacts said optical element during an immersion lithography process; and

supplying said cleaning liquid into said gap through said switching device such that said cleaning liquid contacts said optical element during a cleanup process, whereby said optical element is cleaned.

11. The cleanup method of claim 1 wherein the cleanup process results in removal of debris from the optical element

12. An immersion lithography apparatus comprising:

a reticle stage arranged to retain a reticle;

a working stage arranged to retain a workpiece;

an optical system including an illumination source and an optical element, said optical element being opposite said working stage, the optical system being configured to project an image pattern of said reticle on said workpiece by radiation from said illumination source;

a gap being defined between said optical element and said workpiece;

a fluid-supplying device to provide an immersion liquid between and contacting said optical element and said workpiece during an immersion lithography process; and

a cleaning device to clean said optical element during a cleanup process.

13. The immersion lithography apparatus of claim 12 wherein said cleaning device includes a reservoir that stores a material with affinity to said immersion liquid.

14. The immersion lithography system of claim 13 wherein said immersion liquid is water and said material is ethanol.

15. The immersion lithography system of claim 12 wherein said cleaning device includes a heat-generating device for heating said optical element and thereby removing absorbed liquid by said optical element.

16. The immersion lithography system of claim 12 wherein said cleaning device includes a vacuum device for generating a vacuum condition on said optical element and thereby removing the absorbed liquid by said optical element.

17. The immersion lithography system of claim 12 wherein said cleaning device includes an ultrasonic vibrator for subjecting said optical element to ultrasonic vibrations.

18. The immersion lithography system of claim 17 wherein said ultrasonic vibrator is attached to a housing for said optical element.

19. The immersion lithography system of claim 17 wherein said ultrasonic vibrator serves to transmit ultrasonic vibrations to said optical element through a liquid in said gap.

20. The immersion lithography system of claim 12 wherein said cleaning device includes a bubble-generating device for generating cavitating bubbles in a liquid in said gap.

21. The immersion lithography system of claim 11 wherein said cleaning device includes a switching device incorporated in said fluid-supplying device for selectively causing said immersion liquid to be supplied into said gap during said immersion lithography process and a cleaning liquid to be supplied into said gap during said cleanup process whereby the absorbed liquid by said optical element is removed.

22. An object manufactured with the immersion lithography apparatus of claim 12.

23. A wafer on which an image has been formed by the immersion lithography apparatus of claim 12.

24. A method for making an object using a lithography process, wherein the lithography process utilizes the immersion lithography apparatus of claim 12.

25. A method for patterning a wafer using a lithography process, wherein the lithography process utilizes the immersion lithography system of claim 12.

26. A cleanup method for an optical element in immersion lithography apparatus, said method comprising:

immersing the optical element in an liquid; and

cleaning the immersed optical element during a cleanup process.

27. The cleanup method of claim 26 wherein the optical element is part of a projection system of the immersion lithography apparatus, the projection system configured to project a pattern image onto a workpiece.

28. The cleanup method of claim 26 wherein the cleanup is performed with light.

29. The cleanup method of claim 28 wherein the light is ultraviolet light.

30. The cleanup method of claim 28 wherein the light has a wavelength used during an exposure operation when the projection system projects the pattern onto the workpiece.

31. The cleanup method of claim 26 further comprising supplying and recovering immersion liquid from the area where the optical element is immersed, the immersion liquid being supplied and recovered during the cleaning of the immersion optical element during the cleanup process.

32. The cleanup method of claim 31 wherein the cleanup is carried out with light.

33. The cleanup method of claim 32 wherein the light is ultraviolet light.

34. The cleanup method of claim 33 wherein the light is exposure light.

35. The cleanup method of claim 31 wherein the immersion lithography has a supply and recovery unit which supplies and collects an immersion liquid through which a workpiece is exposed to exposure light and the optical element is immersed in the immersion liquid from the supply unit during the cleanup process.

36. The cleanup method of claim 1 wherein the cleanup is performed with light.

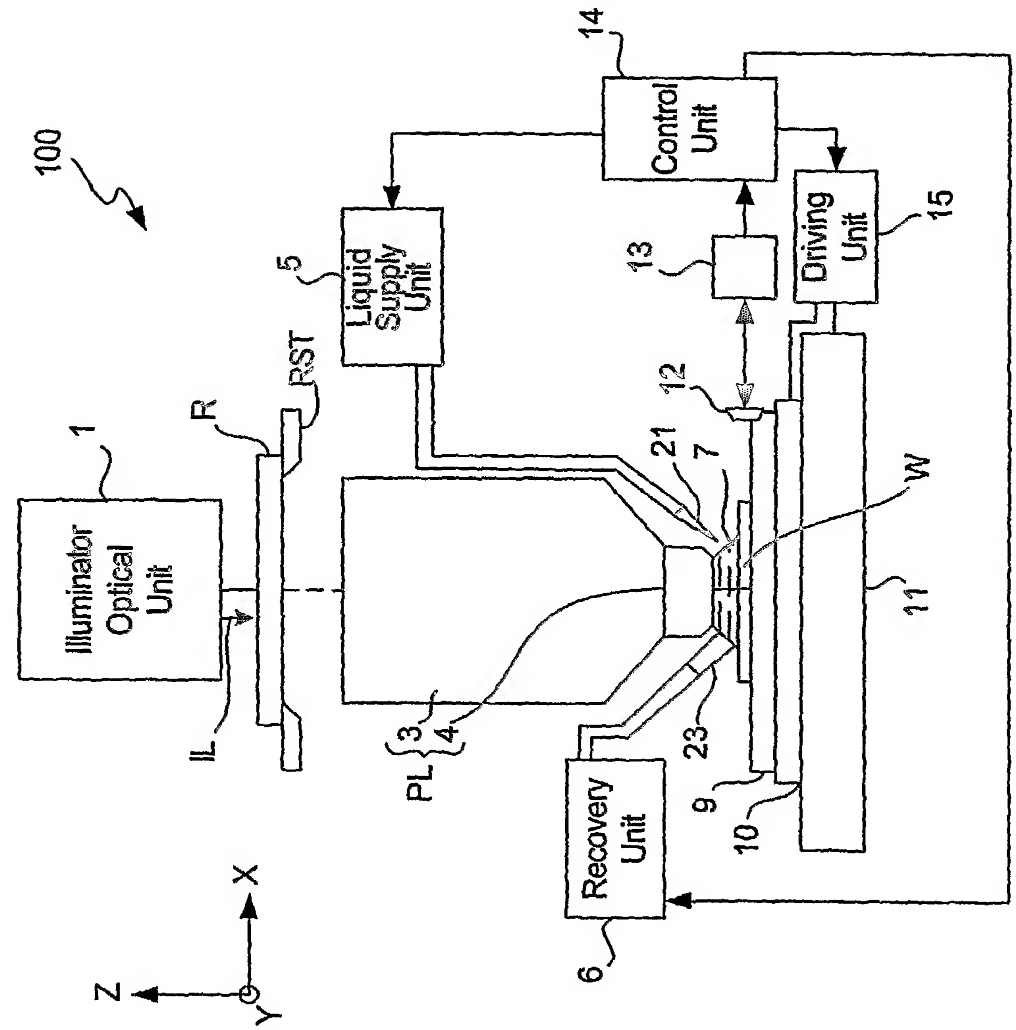
37. The cleanup method of claim 36 wherein the light is ultraviolet light.

38. The cleanup method of claim 36 wherein the light has a wavelength used during an exposure operation when the projection system projects the pattern onto the workpiece.

39. The immersion lithography apparatus of claim 12 wherein the cleanup is performed with light.

40. The immersion lithography apparatus of claim 39 wherein the light is ultraviolet light.

41. The immersion lithography apparatus of claim 39 wherein the light has a wavelength used during an exposure operation when the projection system projects the pattern onto the workpiece.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1
IL
R
RST
Liquid Supply Unit
5
Control Unit
14
Driving Unit
15
13
12
21
7
W
11
PL
3
4
23
9
10
Recovery Unit
6
X
Z
Y

FIG. 1

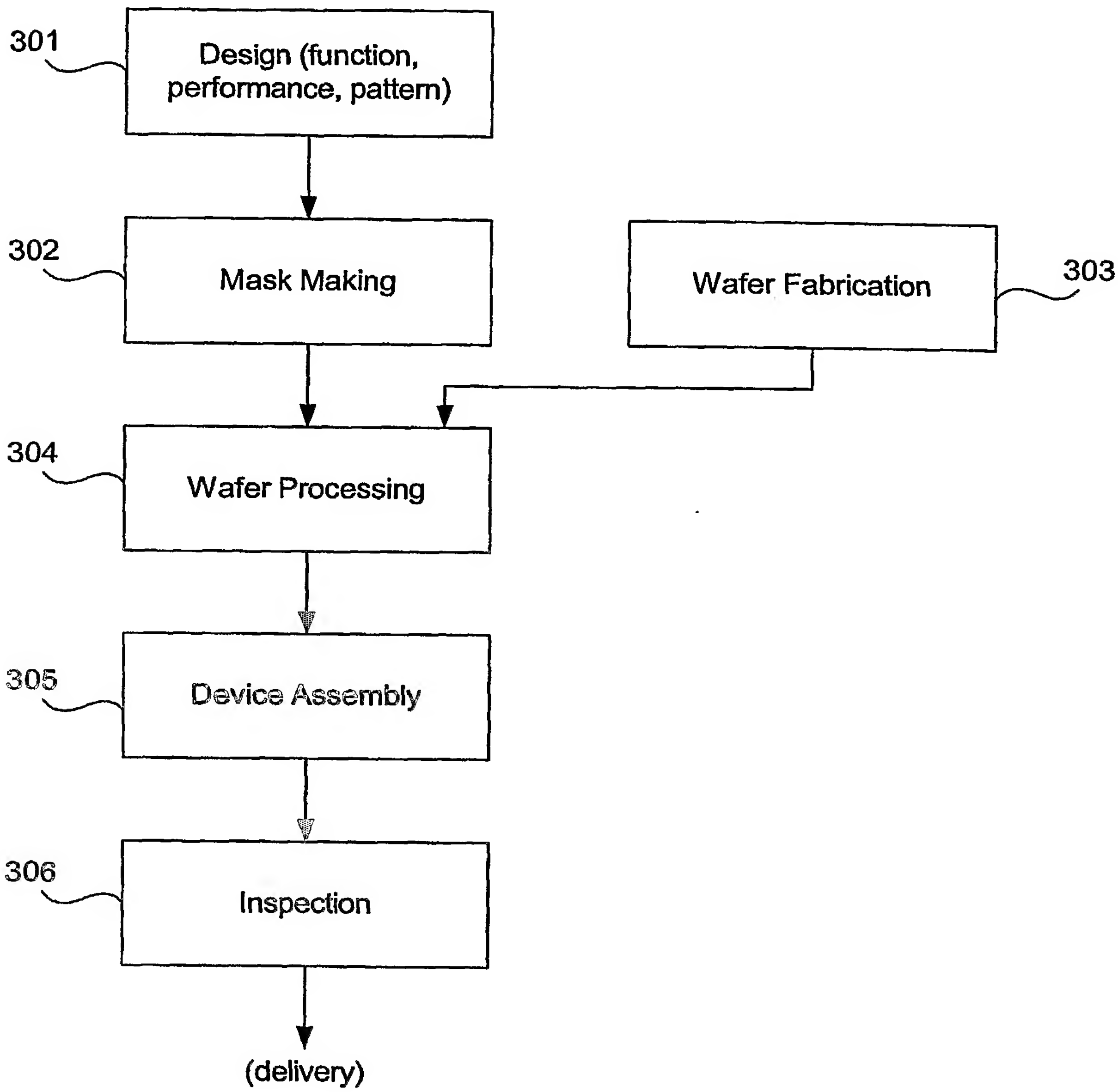
301
Design (function, performance, pattern)
302
Mask Making
Wafer Fabrication
303
304
Wafer Processing
305
Device Assembly
306
Inspection
(delivery)

FIG. 2

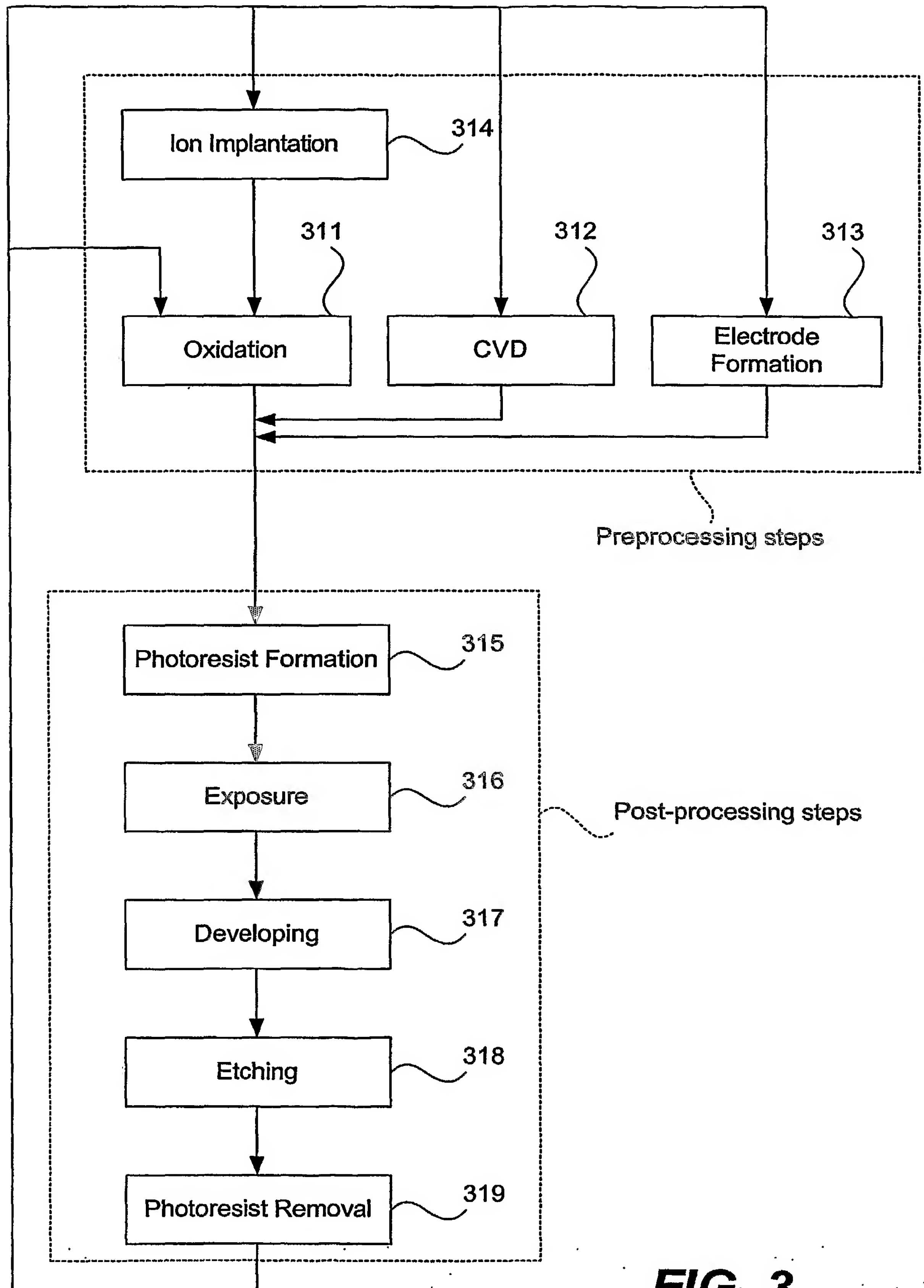
Ion Implantation
314
311
312
313
Oxidation
CVD
Electrode Formation
Preprocessing steps
Photoresist Formation
315
Exposure
316
Post-processing steps
Developing
317
Etching
318
Photoresist Removal
319

FIG. 3

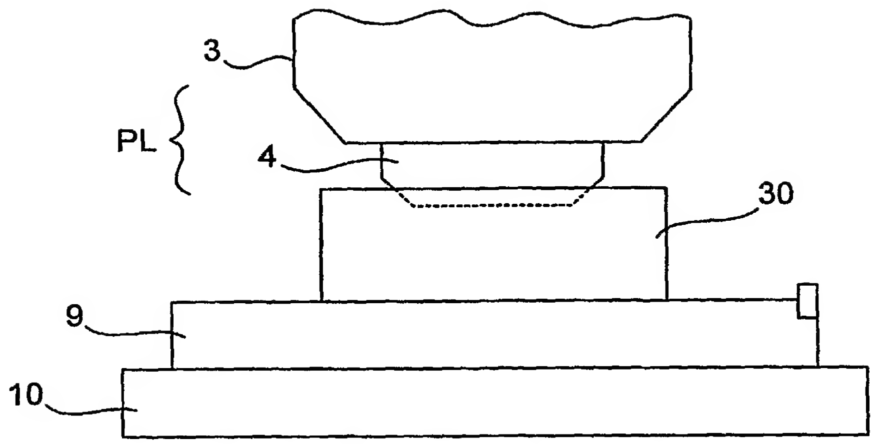

FIG. 4

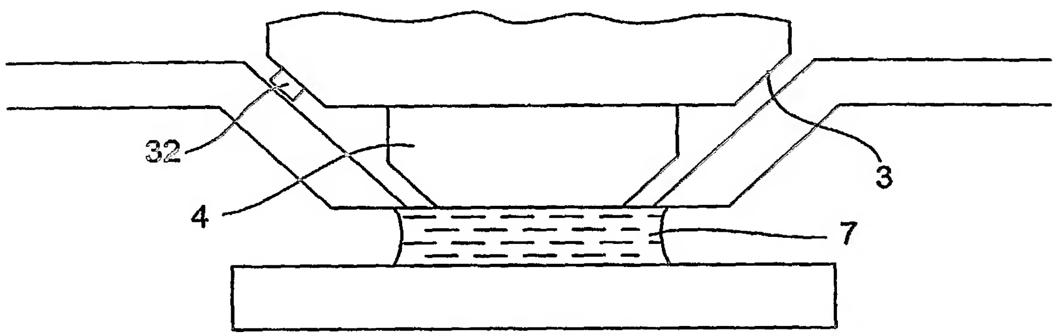

FIG. 5

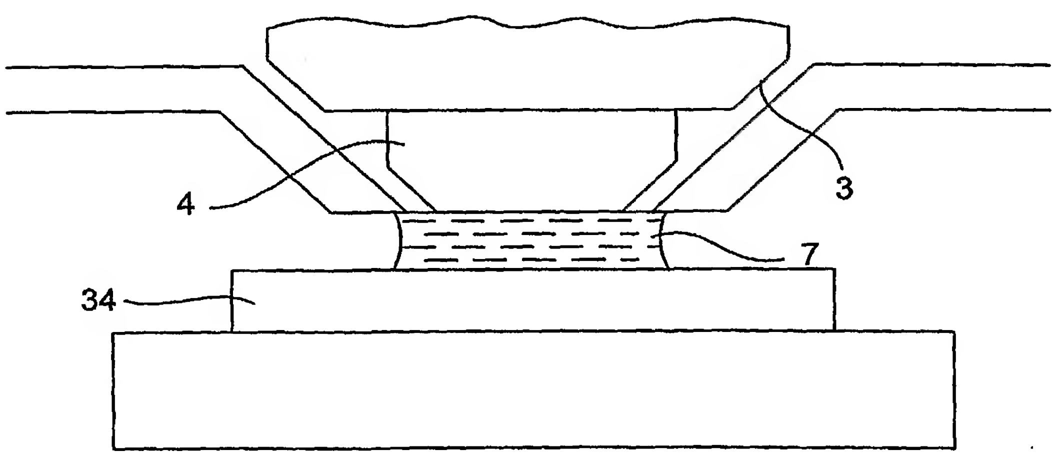

FIG. 6

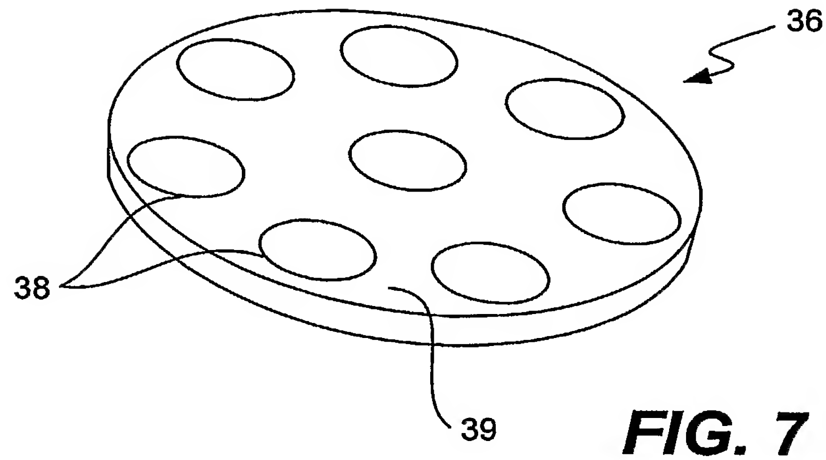

FIG. 7

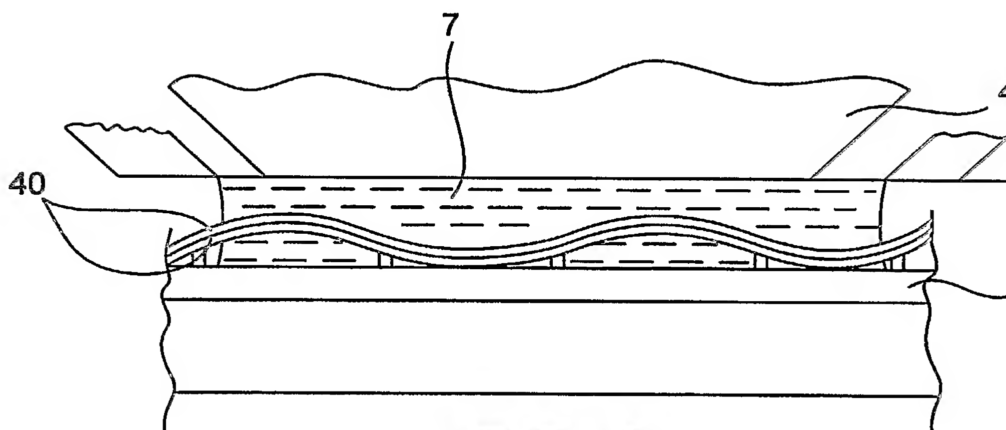

FIG. 8

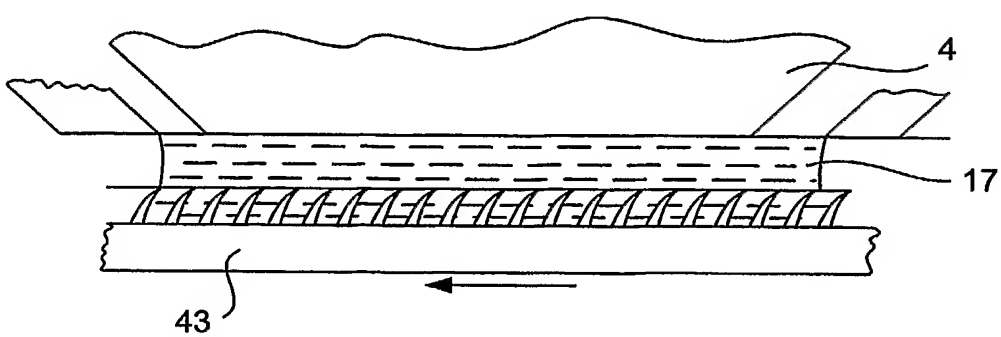

FIG. 9

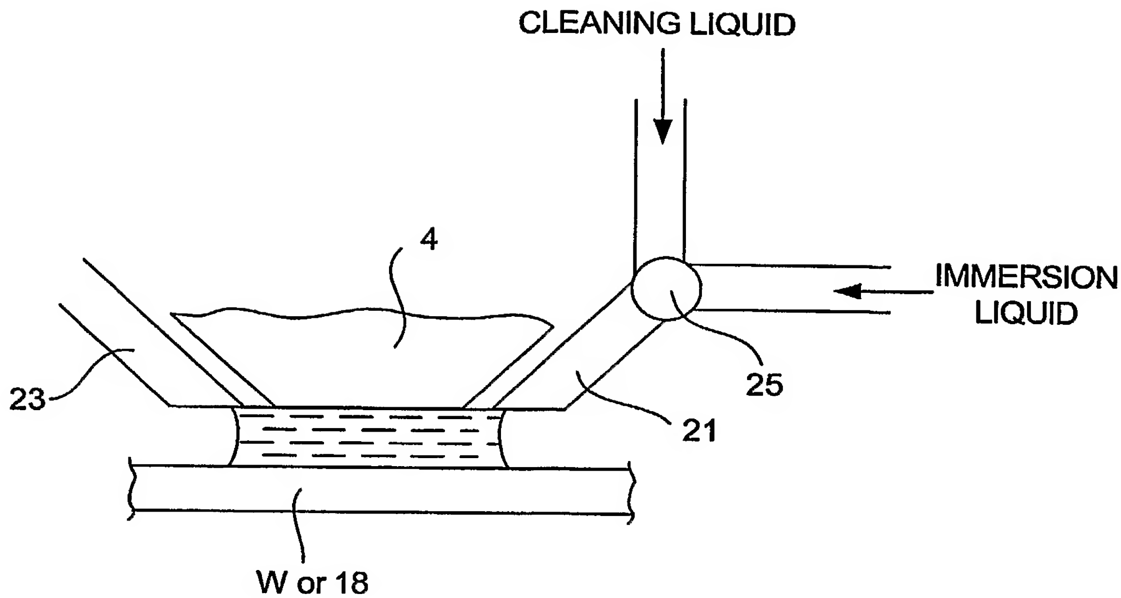

FIG. 10